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See application file for complete search history.

- (56)
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- (57) **ABSTRACT**

- Methods for shutting down and restarting polymerization in a gas phase polymerization reactor are provided. The method can include introducing a polymerization neutralizer to the reactor in an amount sufficient to stop polymerization therein. The method can also include stopping recovery of a polymer product from the reactor and stopping introduction of a catalyst feed and a reactor feed to the reactor. The method can also include adjusting a pressure within the reactor from an operating pressure to an idling pressure. The method can also include adjusting a superficial velocity of a cycle fluid through the reactor from an operating superficial velocity to an idling superficial velocity. The method can also include maintaining the reactor in an idled state for a period of time.

- 19 Claims, 2 Drawing Sheets**

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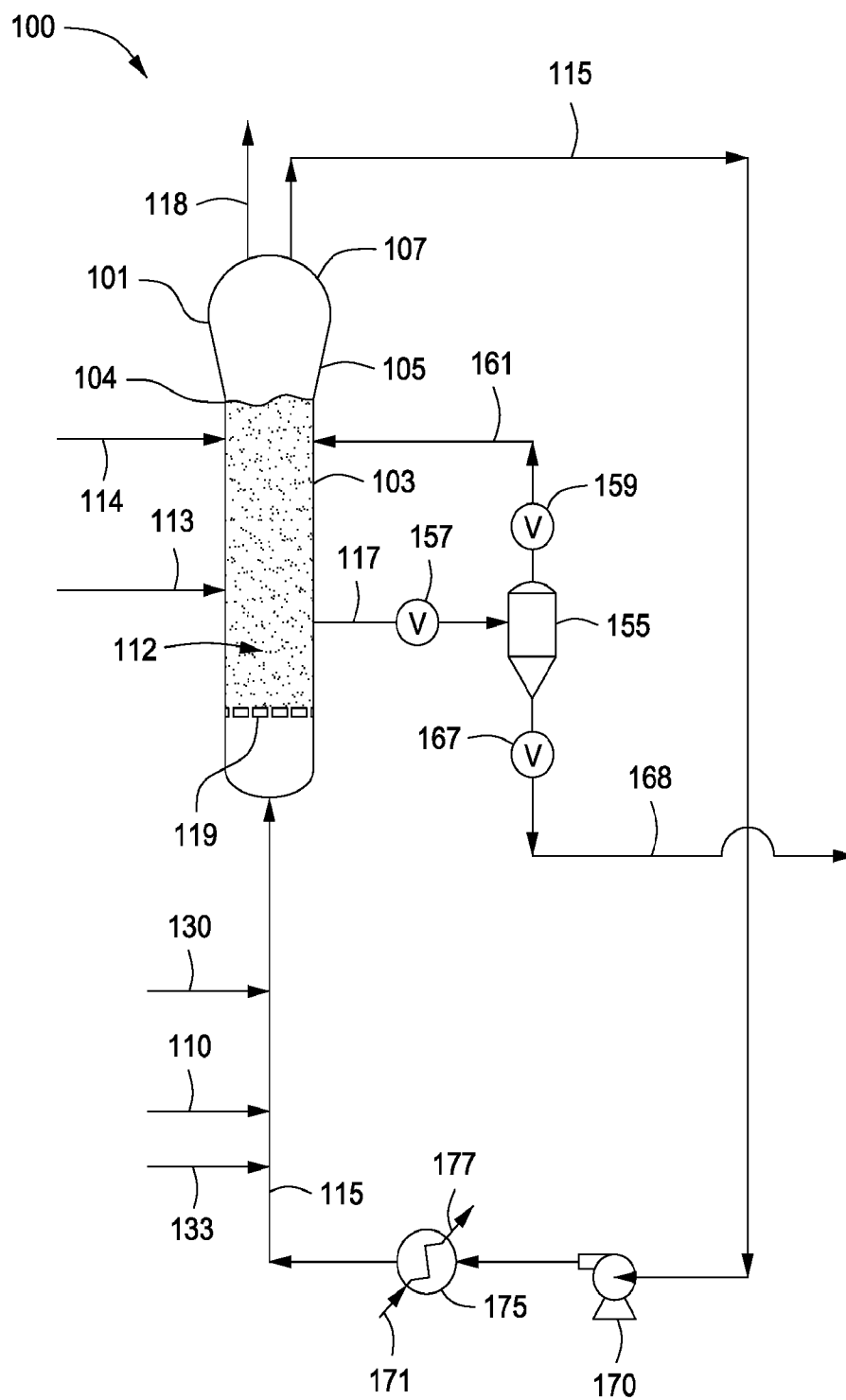


FIG. 1

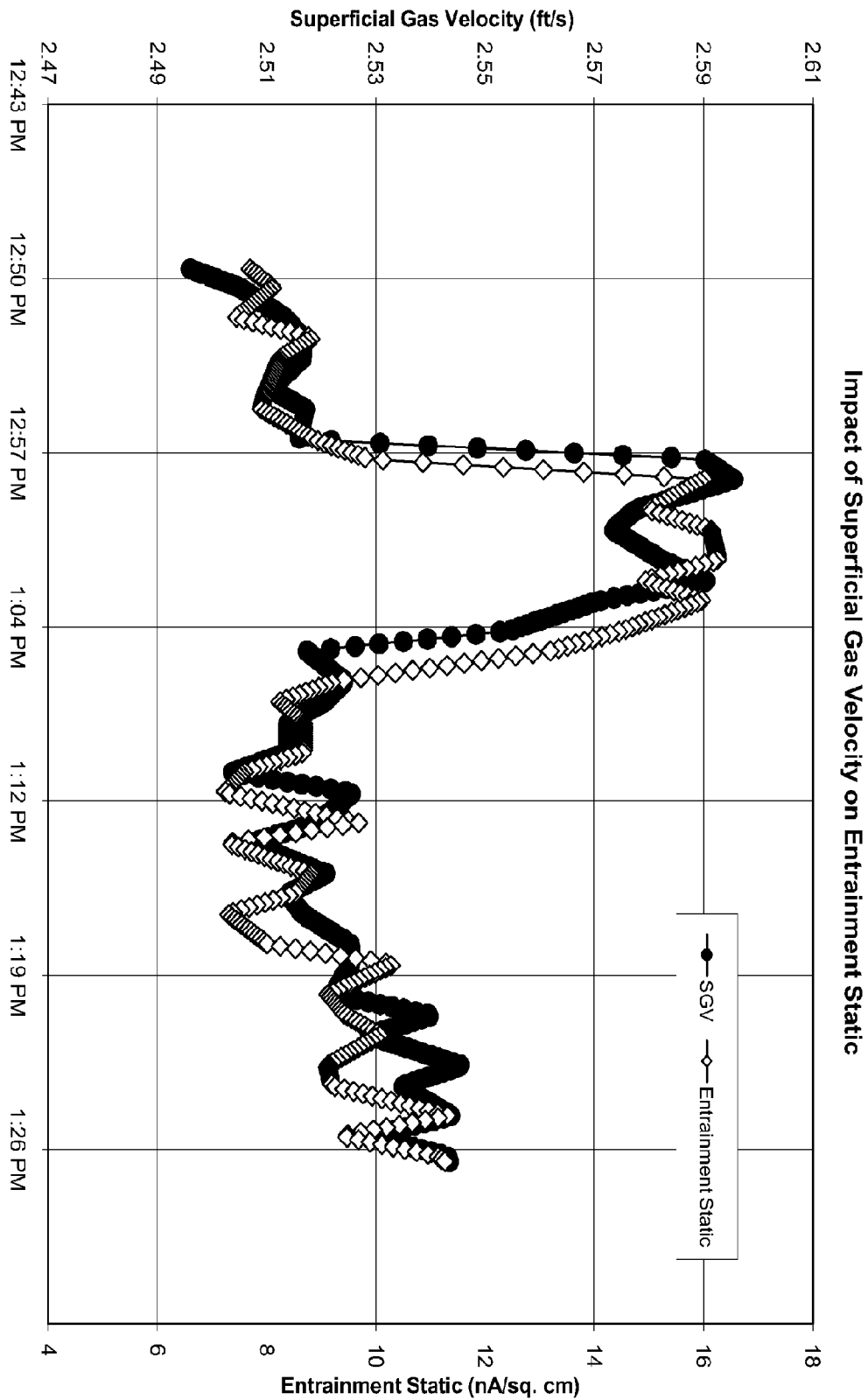


FIG. 2

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# METHODS FOR OPERATING A POLYMERIZATION REACTOR

## CROSS REFERENCE TO RELATED APPLICATIONS

This application is a National Stage application under 35 U.S.C. §371 of International Application No. PCT/US2011/025231, filed Feb. 17, 2011, that claims the benefit of U.S. Provisional Patent Application Ser. No. 61/305,623, filed Feb. 18, 2010, the disclosures of which are incorporated by reference in their entirety.

## FIELD OF THE INVENTION

This disclosure relates to methods for shutting down and restarting polymerization in a gas phase polymerization reactor.

## BACKGROUND

In gas phase polymerization, a gaseous stream containing one or more monomers is passed through a fluidized bed under reactive conditions in the presence of a catalyst. A polymer product is withdrawn from the reactor. Fresh monomer is introduced to the reactor to replace the removed polymer product, and any unreacted monomer is recycled back to the reactor.

Process upsets in an ancillary system upstream and/or downstream of the reactor frequently require the polymerization to be shutdown or “killed.” Shutdown procedures are often accompanied with a buildup of catalyst and polymer on the walls of the reactor, which is known as “sheeting.” Another common problem is the buildup of catalyst and polymer on the internal distribution plate, injection nozzle(s), and/or product discharge nozzle(s), which is known as “plugging” or “plate fouling.”

Typical kill procedures require the reactor to be opened, purged of hydrocarbons, emptied of polymer and catalyst particles, cleaned, and reloaded with the removed bed or a new bed to provide a “seedbed” of polymer. This process is time consuming, expensive, and allows impurities, such as moisture and air, to enter the reactor. Such impurities necessitate another time consuming procedure to remove, which typically involves a nitrogen purge to reduce the impurity levels to less than 10 ppm, before restarting the reactor. There is a need, therefore, for improved methods for shutting down and restarting polymerization in a gas phase polymerization reactor.

## SUMMARY

Methods for operating a gas phase polymerization reactor are provided. The method can include introducing a polymerization neutralizer to the reactor in an amount sufficient to stop polymerization therein. The method can also include stopping recovery of a polymer product from the reactor and stopping introduction of a catalyst feed and a reactor feed to the reactor. The method can also include adjusting a pressure within the reactor from an operating pressure to an idling pressure. The method can also include adjusting a superficial velocity of a cycle fluid through the reactor from an operating superficial velocity to an idling superficial velocity. The method can also include maintaining the reactor in an idled state for a period of time.

Another method for operating a gas phase polymerization reactor can include stopping polymerization within the reac-

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tor by introducing carbon monoxide to the reactor such that the concentration of carbon monoxide within the reactor is at least 5 ppmv. The method can also include stopping recovery of a polymer product and stopping introduction of a catalyst feed and a reactor feed to the reactor. The method can also include reducing a concentration of hydrocarbons within the reactor to produce a gas mixture within the reactor that comprises less than about 20 vol % hydrocarbons and about 80 vol % or more inert gases; reducing a pressure within the reactor from an operating pressure to an idling pressure; and reducing an operating superficial velocity of a cycle fluid flowing through the reactor from an operating superficial velocity to an idling superficial velocity, wherein the cycle fluid comprises the gas mixture. The method can also include maintaining the reactor in an idled state for a period of time.

## BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 depicts a schematic of an illustrative gas phase polymerization system for making polymers.

FIG. 2 depicts a graphical representation of the superficial gas velocity and entrainment static in Example 3.

## DETAILED DESCRIPTION

The amount of polymerization neutralizer added to the reactor should be sufficient to reduce or stop polymerization therein, without interrupting fluidization within the reactor. An excess amount of polymerization neutralizer, i.e. an amount greater than that necessary to stop polymerization can be used, but more preferably, the amount added is sufficient to reduce the rate of polymerization by about 90%, about 95%, about 98%, about 99%, about 99.9%, about 99.99%, about 99.999%, or 100%. A 99% reduction in the rate of polymerization means that polymerization is occurring at only 1% of the original rate of polymerization prior to the introduction of the polymerization neutralizer. A 100% reduction in the polymerization rate means that no polymerization is occurring within the reactor.

The amount or concentration of the polymerization neutralizer within the reactor can vary depending on the size of the reactor and the desired time frame for the polymerization interruption. For example, the amount or concentration of the polymerization neutralizer within the reactor can be at least 1 part per million by volume (“ppmv”), about 5 ppmv, about 10 ppmv, about 30 ppmv, about 50 ppmv, about 100 ppmv, about 250 ppmw, about 500 ppmw, or about 1,000 ppmw. In another example, the amount or concentration of the polymerization neutralizer within the reactor can range from a low of about 1 ppmv, about 2 ppmv, or about 3 ppmv to a high of about 10 ppmv, about 30 ppmv, or about 50 ppmv. During idling of the reactor the concentration of the polymerization neutralizer can be maintained at a minimum concentration of about 1 ppmv, about 2 ppmv, about 3 ppmv, about 4 ppmv, about 5 ppmv, about 6 ppmv, about 7 ppmv, about 8 ppmv, about 9 ppmv, or about 10 ppmv.

The polymerization neutralizer can be added to the reactor from any location or number of locations within the polymerization system. For example, the polymerization neutralizer can be introduced directly to the reactor, with the reactor feed, the catalyst feed, to the cycle fluid, or any combination thereof. Preferably the polymerization neutralizer is introduced directly to the reactor and/or to the cycle fluid.

Suitable polymerization neutralizers can include, but are not limited to, one or more Lewis bases such as carbon monoxide, carbon dioxide, water, or any combination thereof. In one example, the polymerization neutralizer can include car-

bon monoxide, carbon dioxide, or a combination thereof. In another example, the polymerization neutralizer can be carbon monoxide.

The recovery of polymer product can be adjusted, i.e., reduced, increased and/or stopped, at any time before, after, or at the same time the polymerization neutralizer is introduced to the reactor. For example, recovery of the polymer product can be stopped when the polymerization neutralizer is introduced to the reactor. In another example, the polymer product can be stopped within about  $\pm 1$  minute, about  $\pm 5$  minutes, or about  $\pm 10$  minutes of the time the polymerization neutralizer is introduced to the reactor.

The rate the reactor feed is introduced to the reactor can also be adjusted, i.e., reduced, increased and/or stopped, at any time before, after, or at the same time the polymerization neutralizer is introduced to the reactor. For example, introduction of the reactor feed can be stopped when the polymerization neutralizer is introduced to the reactor. In another example, introduction of the reactor feed can be stopped within about  $\pm 1$  minute, about  $\pm 5$  minutes, or about  $\pm 10$  minutes of the time the polymerization neutralizer is introduced to the reactor.

Each particular component of the reactor feed, e.g. monomer(s), induced condensing agents ("ICAs"), hydrogen, and/or inert gases such as nitrogen, can be stopped at the same time or at different times with respect to one another. For example, all components of the reactor feed can be stopped at the same time. In another example, for a reactor feed having monomer(s) and ICA(s), introduction of the ICA(s) can be stopped prior to introduction of the polymerization neutralizer and introduction of the monomer(s) can be stopped when or after the polymerization neutralizer is introduced to the reactor. In still another example, for a reactor feed having monomer(s) and ICA(s), both the ICA(s) and the monomer(s) can be stopped before the polymerization neutralizer is introduced to the reactor and the introduction of the ICA(s) can be stopped before the introduction of the monomer(s) is stopped.

Further, the rate the catalyst feed is introduced to the reactor can be adjusted, i.e., reduced, increased and/or stopped, at any time before, after, or at the same time the polymerization neutralizer is introduced to the reactor. For example, introduction of the catalyst feed can be stopped when the polymerization neutralizer is introduced to the reactor. In another example, introduction of the catalyst feed can be stopped within about  $\pm 1$  minute, about  $\pm 5$  minutes, or about  $\pm 10$  minutes of the time the polymerization neutralizer is introduced to the reactor.

Each particular component of the catalyst feed, e.g. catalyst(s), activator(s), and/or additives, can be stopped at the same time or different times with respect to one another. For example, all components of the catalyst feed can be stopped at the same time. In another example, for a catalyst feed having a first catalyst system and a second catalyst system, introduction of the first catalyst system can be stopped prior to introduction of the polymerization neutralizer and introduction of the second catalyst system can be stopped when or after the polymerization neutralizer is introduced to the reactor. In still another example, for a catalyst feed having a first catalyst system and a second catalyst system both the first and second catalyst systems can be stopped before the polymerization neutralizer is introduced to the reactor and the introduction of the first catalyst system can be stopped before introduction of the second catalyst system is stopped.

As part of the idling procedure, the pressure within the reactor can be adjusted. The pressure within the reactor can be adjusted by removing at least a portion of the gases and/or liquids from within the reactor or adding gases and/or liquids

to the reactor. For example, the pressure within the reactor can be reduced by venting or purging at least a portion of the gases and/or liquids from within the reactor.

The idling pressure can be less than or greater than the operating pressure. Preferably, the idling pressure is less than the operating pressure. For example, the normal operating pressure within the reactor can range from a low of about 1,000 kPag, about 1,200 kPag, about 1,400 kPag, or about 1,500 kPag to a high of about 1,800 kPag, about 2,200 kPag, about 2,300 kPag, or about 2,400 kPag. During idling, however, the pressure can be reduced to about 500 kPag, about 600 kPag, about 700 kPag, about 800 kPag, or about 900 kPag. The pressure within the reactor can be reduced by venting or purging at least a portion of the gases and/or liquids within the reactor before, when, or after the polymerization neutralizer is introduced to the reactor.

If the pressure within the reactor approaches or falls below a desired idling pressure, gases and/or liquids can be introduced to the reactor to increase the pressure therein. For example, nitrogen can be introduced to the reactor to increase the pressure within the reactor to a desired idling pressure. The idling pressure can be less than the operating pressure, equal to the operating pressure, or greater than the operating pressure of the reactor.

Optionally, the idling procedure can also include adjusting the superficial velocity of cycle fluid flowing through the reactor can be adjusted from an operating superficial velocity to an idling superficial velocity. The pressure drop through the fluidized bed is equal to or slightly greater than the weight of the fluidized bed divided by the cross-sectional area. It is thus dependent on the geometry of the reactor. To maintain a viable fluidized bed in the reactor, the superficial gas velocity through the bed must exceed the minimum flow required for fluidization. During operating conditions, preferably the superficial gas velocity is at least two times the minimum flow velocity. The operating superficial gas velocity can range from a low of about 0.3 m/s, about 0.35 m/s, about 0.4 m/s, or about 0.5 m/s to a high of about 1 m/s, about 1.4 m/s, about 1.8 m/s, or about 2 m/s. Ordinarily, the superficial gas velocity does not exceed 1.5 m/s and usually no more than about 0.8 m/s is sufficient.

The idling superficial velocity can be less than the operating superficial velocity. For example, a reactor with an operating superficial velocity of from about 0.6 to about 0.8 m/s of cycle fluid flow therethrough can be reduced to about 0.5 to about 0.6 m/s during idling, for example about 0.55 m/s. The superficial velocity can be reduced before, after, and/or at the same time the polymerization neutralizer is introduced to the reactor.

The use of lower superficial gas velocity during the idling procedure can aid in decreasing catalyst entrainment static during idling. Small changes in the superficial gas velocity can result in large changes in entrainment static. Thus, reducing or lowering the superficial gas velocity during the idling or start up procedures can decrease the entrainment static. Reductions in the entrainment static can lead to reductions in sheeting and fouling in the reactor. The level of static in the reactor can be measured using a static probe, as described in PCT Publication WO 2008/016478. For example, the level of static in the reactor may be measured using an upper static probe located near the top of the fluidized bed. This upper static probe may provide a measurement of entrainment static, the static at or near the top of the fluidized bed or near the reactor output streams.

Optionally, the composition of the fluid mixture within the reactor can be adjusted from an operating composition to an idling composition. For example, the polymerizable and/or

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modifying components within the polymerization system can be vented as a purge gas from the reactor to reduce the concentration therein. The concentration of polymerizable and/or modifying components within the polymerization system can be reduced to less than about 30 vol %, about 20 vol %, about 17 vol %, about 15 vol %, about 12 vol %, about 10 vol %, about 8 vol %, about 6 vol %, or about 5 vol %. For example, the idling composition of the gas within the polymerization system can have less than about 10 vol % combined polymerizable and modifying gaseous components, e.g. monomers and ICAs, and greater than about 90 vol % inert gases, such as nitrogen. Inert gases such as nitrogen can be introduced to the polymerization system to maintain a sufficient amount of gaseous and/or liquid medium introduced to the reactor as the cycle fluid.

The amount of ICA(s) within the reactor can be reduced prior to stopping the reactor feed and/or the catalyst feed. For example, prior to stopping the polymerizable components and/or hydrogen, if present, the concentration of ICA(s) can be reduced to less than about 17 mol %, less than about 15 mol %, less than about 13 mol %, less than about 11 mol %, or less than about 9 mol %, less than about 7 mol %, less than about 5 mol %, less than about 3 mol %, or less than about 1 mol %. The concentration of ICA(s), if present, can be reduced before, after, and/or at the same time the polymerization neutralizer is introduced to the reactor. For example, the concentration of the ICA(s) can be reduced from an operating concentration to a concentration intermediate operating and idling concentrations before the polymerization neutralizer is introduced to the reactor.

The amount or portion of the cycle fluid condensed when introduced to the reactor can be reduced prior to stopping the reactor feed and/or the catalyst feed. For example, during normal operation the amount of the cycle fluid condensed when introduced to the reactor can range from a low of about 1 wt %, about 5 wt %, or about 10 wt % to a high of about 20 wt %, about 30 wt %, or about 40 wt %. Prior to introducing the polymerization neutralizer and/or stopping the reactor feed and/or the catalyst feed the amount of the cycle fluid condensed when introduced to the reactor can be reduced to less than about 20 wt %, less than about 18 wt %, less than about 16 wt %, less than about 14 wt %, less than about 12 wt %, less than about 10 wt %, less than about 8 wt %, or less than about 6 wt %. For example, the amount of the cycle fluid condensed when introduced to the reactor can be adjusted to range from about 2 wt % to about 17 wt %, about 5 wt % to about 15 wt %, or about 7 wt % to about 13 wt % prior to introducing the polymerization neutralizer and/or stopping the reactor feed and/or the catalyst feed.

The polymerizable and/or modifying gaseous components vented from the reactor can be introduced to a flare or other disposal system or device. If the purged gases are flared, heat can be recovered from the combustion of the hydrocarbons and used, for example to generate steam. The purged gases can also be stored, for example in a storage tank for later introduction into the polymerization system. The purged gases can also be introduced to a subterranean formation for later recovery and use. The purged gases can also be introduced to other refinery processes for the production of one or more chemicals or other products.

Optionally, the temperature within the reactor can be adjusted. The temperature within the reactor can be reduced, before, after, and/or at the same time the polymerization neutralizer is introduced to the reactor. The idling temperature can be about 85° C. or less, about 83° C. or less, about 80° C. or less, or about 77° C. or less. The temperature within the reactor can be maintained at an idling temperature that can

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range from about ambient or "room" temperature to about 79° C., about 82° C., or about 84° C. Reducing or stopping the polymerization within the reactor can reduce or eliminate the heat produced therefrom, which can reduce the temperature within the reactor. The temperature within the reactor can also be reduced and/or maintained by adjusting the temperature of a heat transfer medium used to adjust the temperature of the cycle fluid, for example.

If the ambient temperature outside the reactor is cool, e.g. less than 25° C., the fluidized bed can tend to cool down below a desired idling temperature because of the reduced or lack of heat being generated within the reactor due to a reduced rate or termination of polymerization. To compensate for cooling of the fluidized bed, the temperature of the heat transfer medium can be increased. However, to avoid plate fouling and/or sheeting or other polymer accumulation within the reactor, the temperature of a heat transfer medium used to heat the cycle fluid introduced to the reactor can be monitored and controlled. The temperature of the heat transfer medium can be maintained at a temperature of less than about 95° C., less than about 91° C., less than about 89° C., less than about 85° C., less than about 81° C., less than about 78° C., or less than about 75° C. Increasing the heat transfer medium beyond about 80° C., about 85° C., about 90° C., or about 95° C. could lead to plate fouling or other sheeting within the reactor upon introduction of the cycle fluid thereto.

During normal operation, i.e. polymer production, under a given set of operating conditions the fluidized bed is maintained at essentially a constant height by withdrawing a portion of the bed as polymer product at the rate of formation of the particulate polymer product. Since the rate of heat generation during polymerization is directly related to the rate of product formation, a measurement of the temperature rise of the fluid across the reactor (the difference between inlet cycle fluid temperature and exit cycle fluid temperature) is indicative of the rate of particulate polymer formation at a constant fluid velocity if no or negligible vaporizable liquid is present in the inlet fluid. The temperature rise of the fluid across the reactor, i.e. the temperature of the cycle gas exiting the reactor minus the temperature of the cycle gas introduced to the reactor, can be referred to as "DT" or "ΔT." A normal or typical DT for the reactor during polymer production can range from a low of about 5° C., about 10° C., or about 15° C. to a high of about 40° C., about 50° C., or about 55° C.

During idling of the polymerization system, the DT of the reactor can range from a low of about -15° C., about -11° C., or about -8° C. to a high of about -4° C., about -2° C., or about 0° C. The particular DT can depend on the ambient temperature outside the reactor, the temperature of the heat transfer medium, the size of the particular reactor, or any combination thereof. In at least one example, the temperature within the reactor can be allowed to fall to the surrounding ambient temperature, i.e. heat exchangers used to cool the cycle fluid during operation and/or warm during idling can be bypassed or operated at ambient temperature.

The height of the fluidized bed during idling of the reactor can vary. The height of the fluidized bed can be based, at least in part, on the particular polymer being produced in the reactor at the time the idling procedure is initiated, the particular polymer to be produced after the period of time the reactor is idled, or a combination thereof. Adjusting the rate of recovery of the polymer product can be performed in a manner that adjusts the height of the fluidized bed to a desired level. For example, the height of the fluidized bed can be increased by reducing or stopping the amount of polymer product recovered from the reactor while polymerization is continued, i.e. before the polymerization neutralizer is introduced to the

reactor. In another example, the height of the fluidized bed can be decreased by increasing the amount of polymer product recovered from the reactor, reducing the amount of polymerizable components introduced from the feed stream, or a combination thereof.

It can be desirable to have differing idling fluidized bed heights depending on the particular polymer within the reactor. During normal operation the reactor can be operated such that the height of the fluidized bed ranges from a low of about -1 m, about 0 m, or about 0.2 m to a high of about 0.5 m, about 1 m, or about 1.5 m relative to the neck of the reactor. The "neck" refers to the junction or connection between a cylindrical section and a transition section of the reactor. During idling of the reactor the height of the fluidized bed can fall or decrease if, for example, the superficial velocity of the cycle fluid flowing through the fluidized bed is reduced. As such, it can also be desirable to raise or increase the fluidized bed height prior to introducing the polymerization neutralizer. Prior to introducing the polymerization neutralizer to the reactor and/or stopping the reactor feed and/or the catalyst feed the height of the fluidized bed can be adjusted to about 0 m, about 0.5 m, about 1 m, about 1.5 m, about 2 m, or about 2.5 m above the neck of the reactor. Depending on the particular polymer within the reactor and the height of the fluidized bed prior to introducing the polymerization neutralizer, the height of the fluidized bed during idling can range from a low of about -4 m, about -3 m, or about -2 m to a high of about -1.5 m, about -1 m, or about -0.5 m relative to the neck of the reactor.

The reactor idling procedure can transition the reactor from an operating state to an idled state, where the reactor can remain idle for any desired period of time, i.e. continued circulation of the gases therethrough to maintain a reduced or non-polymerizing fluidized bed therein. The period of time the reactor can be maintained at or in an idled state can range from a few minutes or hours to days or even weeks. For example, the reactor can be maintained in an idled state for a period of time ranging from a low of about 1 hour, about 10 hours, or about 1 day to a high of about 4 days, about 6 days, about 8 days, about 10 days, about 12 days, about 14, or about 16 days.

After the period of time for idling the reactor has passed, a reactor restart procedure can be initiated. Restarting polymerization can include reducing the concentration of the polymerization neutralizer to less than about 3 ppmv, less than about 2 ppmv, less than about 1 ppmv, or less than about 0.5 ppmv. The concentration of the polymerization neutralizer can be reduced by venting a portion of the cycle gas from the reactor. Nitrogen or other inert gases can be introduced to the reactor to maintain a desired volume of cycle gas and pressure within the polymerization system. The reactor feed can also be introduced in addition to or in lieu of the inert gases.

The restart procedure can also include re-introducing the reactor feed, reintroducing the catalyst feed, adjusting the rate gases are removed from the reactor via the vent or purge line, adjusting the superficial velocity of the gases or cycle fluid through the reactor, adjusting the temperature of the heat transfer medium used to adjust the temperature of the cycle fluid, adjusting the pressure within the reactor, re-starting recovery of the polymer product, and/or adjusting the height of the fluidized bed within the reactor. The reintroduction of the catalyst and the reactor feed, the vent recovery rate, adjusting the temperature, pressure, and superficial gas velocity within the reactor, restarting polymer product recovery, adjusting the temperature of the heat transfer medium, and/or the height of the fluidized bed can occur in any order or sequence.

The order or sequence of re-starting the reactor can generally follow the order of reducing the concentration of the polymerization neutralizer within the reactor, restarting the reactor feed, adjusting the height of the fluidized bed within the reactor, restarting the catalyst feed, and restarting polymer product recovery. The pressure can be adjusted during introduction of the reactor feed, e.g. as the reactor feed is introduced to the reactor the pressure therein can increase. If the introduction of the reactor feed alone is insufficient to increase the pressure to the desired pressure, nitrogen or other non-reactive gases can be added thereto. The temperature can be adjusted or maintained at a temperature of from about 80° C. to about 90° C., e.g. 85° C. for any desired period of time. When the catalyst is introduced to the reactor and the concentration of the polymerization neutralizer has been sufficiently reduced polymerization can begin. The heat generated from the polymerization after restarting can increase the temperature within the reactor. To reduce or maintain a desired temperature within the reactor, the temperature of the heat transfer medium can be adjusted such that the cycle fluid has a desired temperature prior to introduction to the reactor.

The reactor feed can be reintroduced at a rate less than a normal operating rate, equal to the normal operating rate, or greater than the normal operating rate. The rates of various components of the reactor feed, e.g. monomer(s), ICA(s), and/or hydrogen can be reintroduced at varying rates. Reintroduction of each component in the reactor feed can begin at the same time or different times with respect to one another. For a reactor feed that includes ethylene, hexene, isopentane, and hydrogen, the reintroduction of each component can be started at different times. For example, reintroduction of the hexene can be started, which can be followed by the ethylene, which can be followed by the isopentane, which can then be followed by the hydrogen. In another example, the hexene, ethylene, and isopentane can all be introduced at about the same time, which can be followed by the reintroduction of hydrogen. In still another example, the introduction of hexene and ethylene can be started, which can be followed by the isopentane and they hydrogen.

The reintroduction of each component of the reactor feed can be continuous or intermittent. The reintroduction of one or more components of the reactor feed can be continuous and the reintroduction of one or more components of the reactor feed can be intermittent. Depending on the particular polymer being produced in the reactor, the particular amount and rate each component is reintroduced can vary during restart and operation of the polymerization system.

As the reactor feed and/or inert gases are reintroduced to the reactor, the pressure within the reactor can be increased from the idling pressure to an operating pressure or a pressure intermediate the idling pressure and the operating pressure. For example, if the idling pressure ranges from about 600 kPag to about 800 kPag and the desired operating pressure ranges from about 2,000 kPag to about 2,400 kPag the pressure within the reactor can be increased to an intermediate pressure of from about 1,700 kPag to about 1,900 kPag by the reintroduction of the reactor feed and/or inerts. Once polymerization has restarted, i.e. after reintroduction of the catalyst feed and the reactor feed have been restarted and the concentration of the polymerization neutralizer has sufficiently been decreased, the rate of introducing the reactor feed can be adjusted to the desired operating rates. In another example, the rate of introduction for the reactor feed can be brought to desired operating rates rather than a rate intermediate idling and normal production.

The superficial velocity of the cycle gas through the reactor can be maintained at the idling rate, adjusted to the opera-

tional rate, or adjusted to a rate intermediate the idling rate and the operational rate. Gases or fluid from within the polymerization system can be removed via the vent to maintain a desired reactor pressure and/or to adjust the concentration of one or more components, e.g., monomer(s), ICA(s), hydrogen, and the like. Once the desired pressure and flow rates “restart rates” for each component of the reactor feed are reached the catalyst can be reintroduced to the reactor.

The rate of catalyst initially reintroduced to the reactor can be less than the normal operating rate. The initial rate of catalyst feed reintroduced can range from a low of about 15%, about 20% or about 25% to a high of about 35%, about 40%, or about 50% of the normal operating rate. For example, if catalyst were introduced at a rate of 10 kg/hr during normal operation, the amount of catalyst reintroduced upon restarting can be about 2.7 kg/hr, about 3 kg/hr, about 3.3 kg/hr, or about 3.7 kg/hr. Once polymerization (“light off”) has begun within the reactor, the rate of catalyst introduction can be increased to normal operating rates. Preferably the rate of catalyst introduction increased over a period of time. For example, the rate of catalyst introduction can be increased over a period of time of about 0.5 hours, about 1 hour, about 2 hours, about 3 hours, about 4 hours, about 5 hours, or about 6 hours.

The height of the fluidized bed can be adjusted from an idling height to a restart height that can be less than or greater than the idling height. The particular height of the fluidized bed upon restart can depend, at least in part, on the particular polymer to be produced within the reactor once polymerization begins. For example, the height of the fluidized bed can be increased by introducing a polymer to the fluidized bed. If the reactor is idling and it is desired to increase the height of the fluidized bed, polymer granules, beads, flakes, or the like can be introduced to the reactor, thereby increasing the height of the fluidized bed. In another example, the height of the fluidized bed can be increased by delaying restart of polymer product recovery after polymerization has been restarted.

Once introduction of the catalyst has been restarted and polymerization has been restarted, polymer product recovery can be restarted. The rate of product recovery can be less than the normal operating rate and can increase as the amount of polymer production increases. The production of polymer product can increase as the rate of introducing the catalyst and the reactor feed increases. The production of polymer product can also be increased as the concentration of modifying gaseous and/or liquid components such as ICAs in the reactor feed increase within the reactor. Another way to adjust the height of the fluidized bed can be to delay recovery of the polymer product until the desired fluidized bed height is reached or to increase the rate of polymer product recovery if it is desired to decrease the height of the bed.

The time required to restart the reactor from idling to normal operating conditions can range from a low of about 1 hour, about 3 hours, about 5 hours, or about 7 hours to a high of about 10 hours, about 15 hours, about 20 hours, about 25 hours, or about 30 hours. During restart of the reactor, other typical or normal operating conditions and monitoring procedures can be ran under “modified” or “moderated” conditions or values for a period of time after polymerization is restarted. For example, if the polymerization system is operated in condensed mode, a common technique for monitoring the reactor can include monitoring a stickiness control parameter (“dMRT”) such as a reduced melt initiation temperature or “dMIT” value, which can provide an estimate as to the degree of polymer stickiness within the reactor. Moderated startup or restart conditions can include operating the reactor at a dMIT of about 0° C. or a dMIT within about  $\pm 1^\circ$  C.,

about  $\pm 1.5^\circ$  C., or about  $\pm 2^\circ$  C. for a period of time when the normal dMIT ranges from about 5° C. to about 10° C. Additional details of monitoring a stickiness control parameter can be as discussed and described in U.S. Patent Application Publication No. 2008/0065360 and U.S. Provisional Patent Application No. 60/842,747. Another method for monitoring polymerization can include estimating acoustic emissions within the reactor, which can also provide an estimate as to the degree of polymer stickiness within the reactor. Normal or typical acoustic emissions conditions can be modified such that optimal values during restart vary from those desired during normal polymerization. Additional details of monitoring a polymerization reactor via acoustic emissions can be as discussed and described in U.S. Publication No. 2007/0060721. Another “modified” restart condition can include operating the polymerization system at a level or concentration of ICAs ranging from a low of about 8.5 mol %, about 9 mol %, or about 9.5 mol % to a high of about 10.5 mol %, about 11 mol %, or about 11.5 mol % when a desired normal level would be greater.

Restarting the reactor can begin upon correction or termination of one or more shut down indicators. For example, if the shut down indicator was a malfunction of a discharge tank, termination of the shut down indicator could occur when the malfunction of the discharge tank is corrected. However, after correction of any shut down indicator(s) the polymerization system can continue to remain in an idled state for any desired period of time.

Shutting down or idling the reactor and restarting the reactor can frequently be accompanied with reactor plate fouling. Plate fouling is the amount of polymer that has accumulated on a distributor plate within the reactor. Upon restarting polymerization in a reactor that has been idled the level of plate fouling can increase by less than about 10%, less than about 5%, less than about 4%, less than about 3%, less than about 2%, or less than about 1%. The level or degree of fouling on the distribution plate after restarting the reactor, as compared to before the idling procedure was initiated, can increase by less than about 3.5%, less than about 2.5%, less than about 2%, less than about 1.5%, less than about 1%, or less than about 0.5%. For example, a distributor plate that is at about 26% fouling level can have a fouling of less than about 26.5%, less than about 27%, less than about 27.5%, less than about 28%, or less than about 29% after restarting polymerization within the reactor. In at least one example, the level or degree of fouling on the distribution plate after restarting the reactor, as compared to before initiating the idling procedure, can be unchanged.

The initiation of the reactor idling procedure can be started upon the detection of one or more shut down indicators. The one or more shut down indicators can indicate that polymerization within the reactor should be reduced or stopped. The idling procedure can be carried out in a manner that does not require complete shut down of the polymerization system and/or opening of the reactor. As such, the idling procedure can be described as a “closed-reactor shut down” or “closed-reactor idling.” After the one or more shut down indicators are no longer detected, the reactor can be restarted. In other words, after the reactor is idled for a period of time, polymerization can be restarted, and a polymer product can be produced again. The combination of the idling procedure and the restart procedure can be referred to as a “closed shut down and restart procedure” or a “closed reactor restart procedure.”

Illustrative shut down indicators can include any number of situations or events such as an upstream process upset, a downstream process upset, a transition from a first polymer product to a second polymer product, instructions or orders to



stop polymerization, or any combination thereof. An upstream process upset can include, for example, a loss in a reactor feed such as the polymerizable and/or modifying gaseous and/or liquid components, the catalyst feed, and the like. A downstream process upset can include, for example, a malfunction or failure in a product discharge tank(s), extruder(s), equipment associated therewith, and the like. A transition from one polymer product to another polymer product can include, for example, transitioning from a linear low density polyethylene ("LLDPE") product to a high density polyethylene ("HDPE") product or from a first HDPE product to a second HDPE product. Idling the reactor in preparation for a product transition can reduce the amount of "off grade" polymer product produced during the transition. For example, the production of polymer can be reduced or stopped while the composition of the reactor feed and/or catalyst feed are adjusted.

The reactor feed can include any polymerizable hydrocarbon of combination of hydrocarbons. For example, the reactor feed can be any olefin monomer including substituted and unsubstituted alkenes having two to 12 carbon atoms, such as ethylene, propylene, 1-butene, 1-pentene, 1-hexene, 1-heptene, 1-octene, 4-methylpent-1-ene, 1-decene, 1-dodecene, 1-hexadecene, and the like. The reactor feed can also include non-hydrocarbon gas(es) such as nitrogen and/or hydrogen. The reactor feed can enter the reactor at multiple and different locations. For example, monomers can be introduced into the fluidized bed in various ways including direct injection through a nozzle (not shown) into the fluidized bed. The polymer product can thus be a homopolymer or a copolymer, including a terpolymer, having one or more other monomeric units. For example, a polyethylene product could include at least one or more other olefin(s) and/or comonomer(s).

The reactor feed can also include the one or more modifying components such as one or more ICAs. Illustrative ICAs include, but are not limited to, propane, butane, isobutane, pentane, isopentane, hexane, isomers thereof, derivatives thereof, and combinations thereof. As discussed and described above, the ICAs can be introduced to provide a reactor feed to the reactor having an ICA concentration ranging from a low of about 1 mol %, about 5 mol %, or about 10 mol % to a high of about 25 mol %, about 35 mol %, or about 45 mol %. Typical concentrations of the ICAs can range from about 14 mol %, about 16 mol %, or about 18 mol % to a high of about 20 mol %, about 22 mol %, or about 24 mol %. The reactor feed can include other non-reactive gases such as nitrogen and/or argon. Further details regarding ICAs are described in U.S. Pat. Nos. 5,352,749; 5,405,922; 5,436,304; and 7,122,607; and WO Publication No. 2005/113615(A2).

The catalyst feed can include any catalyst, catalyst system, or combination of catalysts and/or catalyst systems. Illustrative catalysts can include, but are not limited to, Ziegler-Natta catalysts, chromium-based catalysts, metallocene catalysts and other single-site catalysts including Group 15-containing catalysts, bimetallic catalysts, and mixed catalysts. The catalyst system can also include  $\text{AlCl}_3$ , cobalt, iron, palladium, chromium/chromium oxide or "Phillips" catalysts. Any catalyst can be used alone or in combination with any other catalyst.

The term "catalyst system" includes at least one "catalyst component" and at least one "activator," alternately at least one co-catalyst. The catalyst system can also include other components, such as supports, and is not limited to the catalyst component and/or activator alone or in combination. The catalyst system can include any number of catalyst components in any combination as described, as well as any activator in any combination as described.

The term "catalyst component" includes any compound that, once appropriately activated, is capable of catalyzing the polymerization or oligomerization of olefins. Preferably, the catalyst component includes at least one Group 3 to Group 12 atom and optionally at least one leaving group bound thereto. The term "leaving group" refers to one or more chemical moieties bound to the metal center of the catalyst component that can be abstracted from the catalyst component by an activator, thereby producing the species active towards olefin polymerization or oligomerization. Suitable activators are described in detail below.

As used herein, in reference to Periodic Table "Groups" of Elements, the "new" numbering scheme for the Periodic Table Groups are used as in the CRC Handbook of Chemistry and Physics (David R. Lide, ed., CRC Press 81<sup>st</sup> ed. 2000).

Suitable chromium catalysts can include di-substituted chromates, such as  $\text{CrO}_2(\text{OR})_2$ ; where R is triphenylsilane or a tertiary polycyclic alkyl. The chromium catalyst system may further include  $\text{CrO}_3$ , chromocene, silyl chromate, chromyl chloride ( $\text{CrO}_2\text{Cl}_2$ ), chromium-2-ethyl-hexanoate, chromium acetylacetonate ( $\text{Cr}(\text{AcAc})_3$ ), and the like. Other non-limiting examples of chromium catalysts are described in U.S. Pat. No. 6,989,344.

Metallocenes are generally described throughout in, for example, 1 & 2 Metallocene-Based Polyolefins (John Scheirs & W. Kaminsky, eds., John Wiley & Sons, Ltd. 2000); G. G. Hlatky in 181 Coordination Chem. Rev. 243-296 (1999) and in particular, for use in the synthesis of polyethylene in 1 Metallocene-Based Polyolefins 261-377 (2000). Other suitable metallocene catalyst compounds can include, but are not limited to, metallocenes described in U.S. Pat. Nos. 7,179,876; 7,169,864; 7,157,531; 7,129,302; 6,995,109; 6,958,306; 6,884,748; 6,689,847; 5,026,798; 5,703,187; 5,747,406; 6,069,213; 7,244,795; 7,579,415; U.S. Patent Application Publication No. 2007/0055028; and WO Publications WO 97/22635; WO 00/699/22; WO 01/30860; WO 01/30861; WO 02/46246; WO 02/50088; WO 04/022230; WO 04/026921; and WO 06/019494.

The "Group 15-containing catalyst" may include Group 3 to Group 12 metal complexes, wherein the metal is 2 to 8 coordinate, the coordinating moiety or moieties including at least two Group 15 atoms, and up to four Group 15 atoms. For example, the Group 15-containing catalyst component can be a complex of a Group 4 metal and from one to four ligands such that the Group 4 metal is at least 2 coordinate, the coordinating moiety or moieties including at least two nitrogens. Representative Group 15-containing compounds are disclosed in, for example, WO 99/01460; EP A1 0 893 454; EP A1 0 894 005; U.S. Pat. Nos. 5,318,935; 5,889,128 U.S. Pat. No. 6,333,389 B2 and U.S. Pat. No. 6,271,325 B1.

As used herein, the terms "activator" refers to any compound or combination of compounds, supported or unsupported, which can activate a catalyst compound or component, such as by creating a cationic species of the catalyst component. For example, this can include the abstraction of at least one leaving group (the "X" group in the single site catalyst compounds described herein) from the metal center of the catalyst compound/component. Activators can include Lewis acids such as cyclic or oligomeric poly(hydrocarbyl-aluminum oxides) and so called non-coordinating activators ("NCA") (alternately, "ionizing activators" or "stoichiometric activators"), or any other compound that can convert a neutral metallocene catalyst component to a metallocene cation that is active with respect to olefin polymerization. Illustrative Lewis acids include, but are not limited to, aluminoxane (e.g., methylaluminoxane "MAO"), modified aluminoxane (e.g., modified methylaluminoxane "MMAO")

and/or tetraisobutyldialuminoxane "TIBAO"), and alkylaluminum compounds. Ionizing activators (neutral or ionic) such as tri (n-butyl) ammonium tetrakis(pentafluorophenyl) boron may be also be used. Further, a tris(perfluorophenyl) boron metalloid precursor may be used. Any of those activators/precursors can be used alone or in combination with the others.

MAO and other aluminum-based activators are known in the art. Ionizing activators are known in the art and are described by, for example, Eugene You-Xian Chen & Tobin J. Marks, Cocatalysts for Metal-Catalyzed Olefin Polymerization: Activators, Activation Processes, and Structure-Activity Relationships 100(4) Chemical Reviews 1391-1434 (2000). The activators may be associated with or bound to a support, either in association with the catalyst component (e.g., metallocene) or separate from the catalyst component, such as described by Gregory G. Hlatky, Heterogeneous Single-Site Catalysts for Olefin Polymerization 100(4) Chemical Reviews 1347-1374 (2000). There are a variety of methods for preparing aluminosiloxane and modified aluminosiloxanes, non-limiting examples are described in U.S. Pat. Nos. 4,665,208; 4,952,540; 5,091,352; 5,206,199; 5,204,419; 4,874,734; 4,924,018; 4,908,463; 4,968,827; 5,308,815; 5,329,032; 5,248,801; 5,235,081; 5,157,137; 5,103,031; 5,391,793; 5,391,529; 5,693,838; 5,731,253; 5,731,451; 5,744,656; 5,847,177; 5,854,166; 5,856,256; and 5,939,346; and EP 0 561 476; EP 0 279 586; EP 0 594-218; and EP 0 586 665; and WO Publications WO 94/10180 and WO 99/15534.

Illustrative Ziegler-Natta catalyst compounds are disclosed in Ziegler Catalysts 363-386 (G. Fink, R. Mulhaupt and H. H. Brintzinger, eds., Springer-Verlag 1995); EP 103 120; EP 102 503; EP 0 231 102; EP 0 703 246; and U.S. Pat. Nos. RE 33,683; 4,115,639; 4,077,904; 4,302,565; 4,302,566; 4,482,687; 4,564,605; 4,721,763; 4,879,359; 4,960,741; 5,518,973; 5,525,678; 5,288,933; 5,290,745; 5,093,415; and 6,562,905; and U.S. Patent Application Publication No. 2008/0194780. Examples of such catalysts include those comprising Group 4, 5 or 6 transition metal oxides, alkoxides and halides, or oxides, alkoxides and halide compounds of titanium, zirconium or vanadium; optionally in combination with a magnesium compound, internal and/or external electron donors (alcohols, ethers, siloxanes, etc.), aluminum or boron alkyl and alkyl halides, and inorganic oxide supports.

The mixed catalyst can be a bimetallic catalyst composition or a multi-catalyst composition. As used herein, the terms "bimetallic catalyst composition" and "bimetallic catalyst" include any composition, mixture, or system that includes two or more different catalyst components, each having a different metal group. The terms "multi-catalyst composition" and "multi-catalyst" include any composition, mixture, or system that includes two or more different catalyst components regardless of the metals. Therefore, the terms "bimetallic catalyst composition," "bimetallic catalyst," "multi-catalyst composition," and "multi-catalyst" will be collectively referred to herein as a "mixed catalyst" unless specifically noted otherwise. In one example, the mixed catalyst includes at least one metallocene catalyst component and at least one non-metallocene component.

The catalyst compositions can include a support material or carrier. As used herein, the terms "support" and "carrier" are used interchangeably and are any support material, including a porous support material, for example, talc, inorganic oxides, and inorganic chlorides. The catalyst component(s) and/or activator(s) can be deposited on, contacted with, vaporized with, bonded to, or incorporated within, adsorbed or absorbed in, or on, one or more supports or carriers. Other support materials can include resinous support

materials such as polystyrene, functionalized or crosslinked organic supports, such as polystyrene divinyl benzene polyolefins or polymeric compounds, zeolites, clays, or any other organic or inorganic support material and the like, or mixtures thereof.

Inorganic oxides supports can include Group 2, 3, 4, 5, 13 or 14 metal oxides. The preferred supports include silica, which may or may not be dehydrated, fumed silica, alumina (see, for example, PCT Publication WO 99/60033), silica-alumina and mixtures thereof. Other useful supports include magnesia, titania, zirconia, magnesium chloride (U.S. Pat. No. 5,965,477), montmorillonite (EP 0 511 665), phyllosilicate, zeolites, talc, clays (U.S. Pat. No. 6,034,187), and the like. Also, combinations of these support materials may be used, for example, silica-chromium, silica-alumina, silica-titania and the like. Additional support materials may include those porous acrylic polymers described in EP 0 767 184, which is incorporated herein by reference. Suitable catalyst supports can be similar to those described in Hlatky, Chem. Rev. (2000), 100, 1347 1376 and Fink et al., Chem. Rev. (2000), 100, 1377 1390, U.S. Pat. Nos. 4,701,432, 4,808,561, 4,912,075, 4,925,821, 4,937,217, 5,008,228, 5,238,892, 5,240,894, 5,332,706, 5,346,925, 5,422,325, 5,466,649, 5,466,766, 5,468,702, 5,529,965, 5,554,704, 5,629,253, 5,639,835, 5,625,015, 5,643,847, 5,665,665, 5,698,487, 5,714,424, 5,723,400, 5,723,402, 5,731,261, 5,759,940, 5,767,032, 5,770,664, and 5,972,510, and WO 95/32995, WO 95/14044, WO 96/06187, WO 97/02297, WO 99/47598, WO 99/48605, and WO 99/50311.

The polymer product(s) produced in the reactor can be or include any type of polymer or polymeric material. For example, the polymer product can include homopolymers of olefins (e.g., homopolymers of ethylene), and/or copolymers, terpolymers, and the like of olefins, particularly ethylene, and at least one other olefin. Illustrative polymers can include, but are not limited to, polyolefins, polyamides, polyesters, polycarbonates, polysulfones, polyacetals, polylactones, acrylonitrile-butadiene-styrene polymers, polyphenylene oxide, polyphenylene sulfide, styrene-acrylonitrile polymers, styrene maleic anhydride, polyimides, aromatic polyketones, or mixtures of two or more of the above. Suitable polyolefins can include, but are not limited to, polymers comprising one or more linear, branched or cyclic C<sub>2</sub> to C<sub>40</sub> olefins, preferably polymers comprising propylene copolymerized with one or more C<sub>3</sub> to C<sub>40</sub> olefins, preferably a C<sub>3</sub> to C<sub>20</sub> alpha olefin, more preferably C<sub>3</sub> to C<sub>10</sub> alpha-olefins. More preferred polyolefins include, but are not limited to, polymers comprising ethylene including but not limited to ethylene copolymerized with a C<sub>3</sub> to C<sub>40</sub> olefin, preferably a C<sub>3</sub> to C<sub>20</sub> alpha olefin, more preferably propylene and or butene.

Preferred polymers include homopolymers or copolymers of C<sub>2</sub> to C<sub>40</sub> olefins, preferably C<sub>2</sub> to C<sub>20</sub> olefins, preferably a copolymer of an alpha-olefin and another olefin or alpha-olefin (ethylene is defined to be an alpha-olefin for purposes of this invention). Preferably, the polymers are or include homo polyethylene, homo polypropylene, propylene copolymerized with ethylene and or butene, ethylene copolymerized with one or more of propylene, butene or hexene, and optional dienes. Preferred examples include thermoplastic polymers such as ultra low density polyethylene, very low density polyethylene ("VLDPE"), linear low density polyethylene ("LLDPE"), low density polyethylene ("LDPE"), medium density polyethylene ("MDPE"), high density polyethylene ("HDPE"), polypropylene, isotactic polypropylene, highly isotactic polypropylene, syndiotactic polypropylene, random copolymer of propylene and ethylene and/or butene and/or hexene, elastomers such as ethylene propylene rubber, ethyl-

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ene propylene diene monomer rubber, neoprene, and blends of thermoplastic polymers and elastomers, such as for example, thermoplastic elastomers and rubber toughened plastics.

FIG. 1 depicts a flow diagram of an illustrative gas phase polymerization system 100 for making polymers, according to one or more embodiments. The polymerization system 100 can include a reactor 101 in fluid communication with one or more discharge tanks 155 (only one shown), compressors 170 (only one shown), and heat exchangers 175 (only one shown). The polymerization system 100 can also include more than one reactor 101 arranged in series, parallel, or configured independent from the other reactors, each reactor having its own associated discharge tanks 155, compressors 170, and heat exchangers 175, or alternatively, sharing any one or more of the associated discharge tanks 155, compressors 170, and heat exchangers 175. For simplicity and ease of description, the polymerization system 100 will be further described in the context of a single reactor train.

The reactor 101 can include a cylindrical section 103, a transition section 105, and a velocity reduction zone or dome 107. The cylindrical section 103 is disposed adjacent the transition section 105. The transition section 105 can expand from a first diameter that corresponds to the diameter of the cylindrical section 103 to a larger diameter adjacent the dome 107. As mentioned above, the location or junction at which the cylindrical section 103 connects to the transition section 105 is referred to as the “neck” or the “reactor neck” 104. The dome 107 has a bulbous shape. One or more cycle fluid lines 115 and vent lines 118 can be in fluid communication with the top head 107. The reactor 101 can include the fluidized bed 112 in fluid communication with the top head 107.

In general, the height to diameter ratio of the cylindrical section 103 can vary in the range of from about 2:1 to about 5:1. The range, of course, can vary to larger or smaller ratios and depends, at least in part, upon the desired production capacity and/or reactor dimensions. The cross-sectional area of the dome 107 is typically within the range of from about 2 to about 3 multiplied by the cross-sectional area of the cylindrical section 103.

The velocity reduction zone or dome 107 has a larger inner diameter than the fluidized bed 112. As the name suggests, the velocity reduction zone 107 slows the velocity of the gas due to the increased cross-sectional area. This reduction in gas velocity allows particles entrained in the upward moving gas to fall back into the bed, allowing primarily only gas to exit overhead of the reactor 101 through the cycle fluid line 115. The cycle fluid recovered via line 115 can contain less than about 10% wt, less than about 8% wt, less than about 5% wt, less than about 4% wt, less than about 3% wt, less than about 2% wt, less than about 1% wt, less than about 0.5% wt, or less than about 0.2% wt of the particles entrained in fluidized bed 112.

The reactor feed via line 110 can be introduced to the polymerization system 100 at any point. For example, the reactor feed via line 110 can be introduced to the cylindrical section 103, the transition section 105, the velocity reduction zone 107, to any point within the cycle fluid line 115, or any combination thereof. Preferably, the reactor feed 110 is introduced to the cycle fluid in line 115 before or after the heat exchanger 175. In the Figure, the reactor feed via line 110 is depicted entering the cycle fluid in line 115 after the heat exchanger 175. The catalyst feed via line 113 can be introduced to the polymerization system 100 at any point. Preferably the catalyst feed via line 113 is introduced to the fluidized bed 112 within the cylindrical section 103.

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The cycle fluid via line 115 can be compressed in the compressor 170 and then passed through the heat exchanger 175 where heat can be exchanged between the cycle fluid and a heat transfer medium. For example, during normal operating conditions a cool or cold heat transfer medium via line 171 can be introduced to the heat exchanger 175 where heat can be transferred from the cycle fluid in line 115 to produce a heated heat transfer medium via line 177 and a cooled cycle fluid via line 115. In another example, during idling of the reactor 101 a warm or hot heat transfer medium via line 171 can be introduced to the heat exchanger 175 where heat can be transferred from the heat transfer medium to the cycle fluid in line 115 to produce a cooled heat transfer medium via line 117 and a heated cycle fluid via line 115. The terms “cool heat transfer medium” and “cold heat transfer medium” refer to a heat transfer medium having a temperature less than the fluidized bed 112 within the reactor 101. The terms “warm heat transfer medium” and “hot heat transfer medium” refer to a heat transfer medium having a temperature greater than the fluidized bed 112 within the reactor 101. The heat exchanger 175 can be used to cool the fluidized bed 112 or heat the fluidized bed 112 depending on the particular operating conditions of the polymerization system 100, e.g. start-up, normal operation, idling, and shut down. Illustrative heat transfer mediums can include, but are not limited to, water, air, glycols, or the like. It is also possible to locate the compressor 170 downstream from the heat exchanger 175 or at an intermediate point between several heat exchangers 175.

After cooling, all or a portion of the cycle fluid via line 115 can be returned to the reactor 101. The cooled cycle fluid in line 115 can absorb the heat of reaction generated by the polymerization reaction. The heat transfer medium in line 171 can be used to transfer heat to the cycle fluid in line 115 thereby introducing heat to the polymerization system 100 rather than removing heat therefrom. The heat exchanger 175 can be of any type of heat exchanger. Illustrative heat exchangers can include, but are not limited to, shell and tube, plate and frame, U-tube, and the like. For example, the heat exchanger 175 can be a shell and tube heat exchanger where the cycle fluid via line 115 can be introduced to the tube side and the heat transfer medium can be introduced to the shell side of the heat exchanger 175. If desired, several heat exchangers can be employed, in series, parallel, or a combination of series and parallel, to lower or increase the temperature of the cycle fluid in stages.

Preferably, the cycle gas via line 115 is returned to the reactor 101 and to the fluidized bed 112 through fluid distributor plate (“plate”) 119. The plate 119 is preferably installed at the inlet to the reactor 101 to prevent polymer particles from settling out and agglomerating into a solid mass and to prevent liquid accumulation at the bottom of the reactor 101 as well to facilitate easy transitions between processes which contain liquid in the cycle stream 115 and those which do not and vice versa. Although not shown, the cycle gas via line 115 can be introduced into the reactor 101 through a deflector disposed or located intermediate an end of the reactor 101 and the distributor plate 119. Illustrative deflectors and distributor plates suitable for this purpose are described in U.S. Pat. Nos. 4,877,587; 4,933,149; and 6,627,713.

The catalyst feed via line 113 can be introduced to the fluidized bed 112 within the reactor 101 through one or more injection nozzles (not shown) in fluid communication with line 113. The catalyst feed is preferably introduced as pre-formed particles in one or more liquid carriers (i.e. a catalyst slurry). Suitable liquid carriers can include mineral oil and/or liquid or gaseous hydrocarbons including, but not limited to,

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propane, butane, isopentane, hexane, heptane octane, or mixtures thereof. A gas that is inert to the catalyst slurry such as, for example, nitrogen or argon can also be used to carry the catalyst slurry into the reactor **101**. In one example, the catalyst can be a dry powder. In another example, the catalyst can be dissolved in a liquid carrier and introduced to the reactor **101** as a solution. The catalyst via line **113** can be introduced to the reactor **101** at a rate sufficient to maintain polymerization of the monomer(s) therein.

Fluid via line **161** can be separated from a polymer product recovered via line **117** from the reactor **101**. The fluid can include unreacted monomer(s), hydrogen, ICA(s), and/or inerts. The separated fluid can be introduced to the reactor **101**. The separated fluid can be introduced to the recycle line **115** (not shown). The separation of the fluid can be accomplished when fluid and product leave the reactor **101** and enter the product discharge tanks **155** (one is shown) through valve **157**, which can be, for example, a ball valve designed to have minimum restriction to flow when opened. Positioned above and below the product discharge tank **155** can be conventional valves **159**, **167**. The valve **167** allows passage of product therethrough. For example, to discharge the polymer product from the reactor **101**, valve **157** can be opened while valves **159**, **167** are in a closed position. Product and fluid enter the product discharge tank **155**. Valve **157** is closed and the product is allowed to settle in the product discharge tank **155**. Valve **159** is then opened permitting fluid to flow via line **161** from the product discharge tank **155** to the reactor **101**. Valve **159** can then be closed and valve **167** can be opened and any product in the product discharge tank **155** can flow into and be recovered via line **168**. Valve **167** can then be closed. Although not shown, the product via line **168** can be introduced to a plurality of purge bins or separation units, in series, parallel, or a combination of series and parallel, to further separate gases and/or liquids from the product. The particular timing sequence of the valves **157**, **159**, **167**, can be accomplished by use of conventional programmable controllers which are well known in the art.

Another preferred product discharge system which can be alternatively employed is that disclosed in U.S. Pat. No. 4,621,952. Such a system employs at least one (parallel) pair of tanks comprising a settling tank and a transfer tank arranged in series and having the separated gas phase returned from the top of the settling tank to a point in the reactor near the top of the fluidized bed.

The reactor **101** can be equipped with one or more vent lines **118** to allow venting the bed during start up, idling, and/or shut down. The reactor **101** can be free from the use of stirring and/or wall scraping. The cycle line **115** and the elements therein (compressor **170**, heat exchanger **175**) can be smooth surfaced and devoid of unnecessary obstructions so as not to impede the flow of cycle fluid or entrained particles.

The conditions for polymerizations vary depending upon the monomers, catalysts, catalyst systems, and equipment availability. The specific conditions are known or readily derivable by those skilled in the art. For example, the temperatures can be within the range of from about  $-10^{\circ}\text{C}$ . to about  $140^{\circ}\text{C}$ ., often about  $15^{\circ}\text{C}$ . to about  $120^{\circ}\text{C}$ ., and more often about  $70^{\circ}\text{C}$ . to about  $110^{\circ}\text{C}$ . Pressures can be within the range of from about 10 kPag to about 10,000 kPag, such as about 500 kPag to about 5,000 kPag, or about 1,000 kPag to about 2,200 kPag, for example. Additional details of polymerization can be found in U.S. Pat. No. 6,627,713.

As discussed and described above, various systems and/or methods can be used to monitor and/or control the degree or level of fouling within the reactor **101**. For example, if the

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polymerization system **100** is operated in condensed mode, a common technique for monitoring the polymerization can include monitoring a stickiness control parameter ("dMRT") such as a reduced melt initiation temperature or "dMIT" value, which can provide an estimate as to the degree of polymer stickiness within the reactor **101**. Another method for monitoring polymerization can include estimating acoustic emissions within the reactor **101**, which can also provide an estimate as to the degree of polymer stickiness within the reactor **101**.

Other illustrative techniques that can also be used to reduce or eliminate fouling and/or sheeting can include the introduction of finely divided particulate matter to prevent agglomeration, as described in U.S. Pat. Nos. 4,994,534 and 5,200,477 and the addition of negative charge generating chemicals to balance positive voltages or the addition of positive charge generating chemicals to neutralize negative voltage potentials as described in U.S. Pat. No. 4,803,251. Antistatic substances can also be added, either continuously or intermittently to prevent or neutralize electrostatic charge generation. Condensing mode operation, such as disclosed in U.S. Pat. Nos. 4,543,399 and 4,588,790 can also be used to assist in heat removal from the fluid bed polymerization reactor.

Additional reactor details and means for operating the reactor are described in, for example, U.S. Pat. Nos. 3,709,853; 4,003,712; 4,011,382; 4,302,566; 4,543,399; 4,882,400; 5,352,749; and 5,541,270; EP 0802202; and Belgian Patent No. 839,380.

As discussed above, when one or more shut down indicators are detected the reactor idling procedure can be initiated. The polymerization neutralizer via line **130** can be introduced to the polymerization system **100** at any point. As shown, the polymerization neutralizer via line **130** is introduced to the cycle fluid in line **115**. The polymerization neutralizer can also be introduced to the fluidized bed **112** within the cylindrical section **103**, the transition section **105**, and/or the dome **107**.

The recovery of the polymer product via line **117** and introduction of the reactor feed via line **110** and the catalyst feed via line **113** can be reduced or stopped before, after, or simultaneously with the introduction of the polymerization neutralizer via line **130**. For example, recovery of the polymer product via line **117** and introduction of the reactor feed via line **110** and the catalyst feed via line **113** can be stopped when the polymerization neutralizer via line **130** is introduced to the polymerization system **100**.

The pressure within the reactor can be reduced from an operating pressure to an idling pressure by removing at least a portion of the gases within the reactor **101** (the "reactor gases") via line **118**. In addition to removing at least a portion of the reactor gases via vent line **118**, the amount of polymerizable and/or modifying gases can also be reduced. Should the pressure fall below a desired idling pressure or the pressure within the reactor **101** should be increased nitrogen or other inert gases via line **133** can be introduced thereto.

Prior to introducing the polymerization neutralizer via line **130** to the reactor **101** the concentration of the polymerizable and/or modifying components within the reactor **101** such as monomers and/or ICAs can be reduced via the vent line **118**, while polymerization continues within the reactor **101**. The concentration of ICAs within the reactor can be reduced via vent line **118** to a concentration intermediate an idling concentration and a normal operating concentration via vent line **118**.

The superficial velocity of the cycle fluid introduced via line **115** to the reactor **101** can be adjusted from an operational superficial velocity to an idling superficial velocity by con-

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trolling the rate of introduction to the reactor **101**. For example, the flow rate of the cycle fluid in line **115** can be reduced via one or more valves (not shown) to provide a cycle fluid flow through the reactor **101** at a reduced superficial velocity.

After the polymerization neutralizer via line **130** has been introduced to the reactor **101** and introduction of the reactor feed via line **110**, the catalyst feed via line **113** have been reduced or stopped and the pressure and superficial velocity have been adjusted from to an idling pressure and superficial velocity, the reactor **101** can be maintained at these conditions for a period of time. After the period of time, e.g. the shut down indicator(s) is no longer detected, a reactor restart procedure can be initiated.

During idling of the reactor **101**, the concentration of the polymerization neutralizer introduced via line **130** can be monitored. Should the concentration fall below a desired idling concentration then additional polymerization neutralizer via line **130** can be introduced to the reactor **101**. The concentration of the polymerization neutralizer can be monitored via one or more gas chromatographs or other detection equipment in a lab or in fluid communication with the polymerization system.

The restart procedure can also include adjusting the height of the fluidized bed **112** from an idling height to a restart height. The restart height of the fluidized bed **112** can be greater than or less than the height of the fluidized bed during idling. To increase the height of the fluidized bed **112** polymer granules, beads, flakes, or the like can be introduced via line **114** to the reactor **101**, thereby increasing the height of the fluidized bed **112**. To decrease the height of the fluidized bed **112** polymer product can be removed via line **117**.

The concentration of the polymerization neutralizer within the reactor **101** can be reduced via vent line **118**. The reactor feed via line **110** can be increased or restarted before, after, or during the reduction in the concentration of the polymerization neutralizer. The reactor feed via line **110** can include the same polymerizable and/or modifying components as before initiation of the reactor idling procedure or the reactor feed via line **110** can include different polymerizable and/or modifying components. The pressure within the reactor **101** can be adjusted from the idling pressure to the operating pressure or a pressure intermediate the idling pressure and the operating pressure. For example, the pressure within the reactor **101** can be increased by introducing the reactor feed via line **110** and/or inert gases via line **133**. In another example, the pressure within the reactor **101** can be decreased by removing reactor gases via vent line **118**. The superficial velocity of the reactor gases through the reactor **101** can be adjusted from the idling superficial velocity to the operating superficial velocity or a superficial velocity intermediate the idling superficial velocity and the operating superficial velocity.

Polymerization within the reactor can be restarted once the concentration of the polymerization neutralizer has been reduced a sufficient amount. Increasing or restarting introduction of the catalyst feed via line **113** can increase the polymerization within the reactor. The catalyst feed via line **113** can be the same catalyst feed or a different catalyst feed than was introduced to the reactor **101** prior to initiating the reactor idling procedure.

The recovery of the polymer product via line **117** can be increased or restarted before, when, or after polymerization is restarted within the reactor **101**. The recovery of the polymer product via line **117** can be restarted at a normal operating recovery rate for the desired polymer being produced within the reactor or to a product recovery rate intermediate the normal operating recovery rate and the idling recovery rate.

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The temperature within the reactor **101** can be adjusted from an idling temperature to an operating temperature as introduction of the reactor feed via line **110** and the catalyst feed via line **113** is restarted and polymerization is restarted within the reactor. The temperature of the cycle fluid in line **115** can be adjusted via the heat exchanger **175** to provide a cycle gas at a desired temperature. The temperature of the reactor **101** can be adjusted to a normal operating temperature for the polymer product being produced within the reactor **101** or the temperature can be adjusted to a temperature intermediate the normal operating temperature and the idling temperature.

## EXAMPLES

To provide a better understanding of the foregoing discussion, the following non-limiting examples are provided. Although the examples are directed to specific embodiments, they are not to be viewed as limiting the invention in any specific respect. All parts, proportions and percentages are by weight unless otherwise indicated.

MI ( $I_2$ ) can be measured in accordance with ASTM D-1238-E (at 190° C., 2.16 kg weight). Density can be measured according to ASTM D-105.

### Examples 1 and 2

Examples 1 and 2 illustrate two experimental closed reactor shutdown and restart procedures carried out in a commercial scale reactor. The polymerization reactor had a cylindrical section **103**, a transition section **105**, and a velocity reduction section **107**, according to one or more embodiments discussed and described above with reference to FIG. 1. The reactor neck was located 15.9 m from the distributor plate. During normal operating conditions, i.e. before the reactor kill and after restarting the reactor, 1,200 tonnes of polymer day are produced in and recovered from the reactor. For both Examples 1 and 2, the catalyst feed to the reactor was a metallocene catalyst system.

Table 1 shows various operating conditions prior to idling a polymerization system and average conditions for the polymerization system during idling thereof for Examples 1 and 2.

TABLE 1

|  | Ex. 1    | Ex. 2    |
|--|----------|----------|
| Melt Index ( $I_2$ )   | 3.5      | 1.0      |
| Density (g/cm <sup>3</sup> )   | 0.918    | 0.918    |
| Conditions before Introduction of the Polymerization Neutralizer             |          |          |
| Pressure (kPag)  | 2,000    | 2,000    |
| Temperature (° C.)   | 85       | 85       |
| Superficial Velocity of Cycle Fluid (m/sec)                                  | 0.73     | 0.72     |
| Product Recovery Rate (t/hr)   | 36       | 34       |
| Wt % Condensed Cycle Fluid Introduced to Reactor                             | 16       | 11       |
| Fluidized Bed Level (m > neck)   | 0.8      | 0.3      |
| Polymerization Neutralizer Amount Polymerization Neutralizer Introduced (kg) | CO<br>12 | CO<br>12 |
| Conditions During Idling   |          |          |
| CO Concentration (ppmv)  | 0-80     | 0-10     |
| Catalyst Feed (kg/hr)  | 0        | 0        |
| Reactor Feed (t/hr)  | 0        | 0        |
| Nitrogen Feed (t/hr)   | ≤8       | ≤8       |

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TABLE 1-continued

|   | Ex. 1 | Ex. 2 |
|---|-------|-------|
| Pressure (kPag)   | 700   | 750   |
| Temperature (° C.)                                      | 84    | 85    |
| Superficial Velocity of Cycle Fluid (m/sec)             | 0.68  | 0.57  |
| Product Recovery Rate (t/hr)                            | 0     | 0     |
| Fluidized Bed Level (m relative to neck of the reactor) | -3.1  | -2.4  |

Table 2 shows various operating conditions and parameters during and after restart of the polymerization system for Examples 1 and 2. The values or ranges shown are averages or the low/high value over the duration of the restart period, which lasted from about 1.5 to 2.6 hours for Examples 2 and 1, respectively. Since the same polymer product was produced before idling and after restart of polymerization, the reactor was returned to operating conditions similar to the conditions prior to initiation of the idling procedure, as shown in Table 1.

TABLE 2

|   | Ex. 1 | Ex. 2 |
|---|-------|-------|
| Idling Time (hrs)   | 15    | 96    |
| Conditions at Time of Catalyst Feed Introduction            |       |       |
| CO Concentration (ppmv)                                     | 1.0   | 0.1   |
| Ethylene Concentration (mol %)                              | 58.9  | 46.9  |
| 1-Hexene Concentration (mol %)                              | 1.5   | 0.9   |
| Isopentane Concentration (mol %)                            | 4.6   | 4.6   |
| Nitrogen Concentration (mol %)                              | 33.7  | 47.2  |
| Hydrogen Concentration (ppmv)                               | 310   | 170   |
| Other Inerts (mol %)  | 1.3   | 0.4   |
| Pressure (kPag)   | 1,910 | 1,870 |
| Temperature (° C.)  | 82    | 82    |
| Superficial Velocity of Cycle Fluid (m/sec)                 | 0.75  | 0.62  |
| Fluidized Bed Level (m relative to neck of the reactor)     | -2.0  | -1.0  |
| Time to Start of Polymerization (minutes)                   | 10    | 19    |
| Time to Product Recovery after Start of Catalyst Feed (hrs) | 2.3   | 1.6   |
| Incremental Plate Fouling (% of holes plugged)              | 0     | 1     |
| Polymer Properties After Restart of the Reactor             |       |       |
| Melt Index (I2)   | 3.5   | 1.0   |
| Density (g/cm3)   | 0.918 | 0.918 |

As shown in Table 2, in Example 1 the reactor was idled for 15 hours and in Example 2 the reactor was idled for 96. There was no plate fouling observed in Example 1. Surprisingly, in Example 2 the level of plate fouling increased by only about 1%.

## Example 3

Example 3 illustrates the impact of the superficial gas velocity on the entrainment static. The polymerization reactor had a cylindrical section 103, a transition section 105, and a velocity reduction section 107, according to one or more

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embodiments discussed and described above with reference to FIG. 1. Table 3 shows various operating conditions in the reactor during Example 3.

TABLE 3

|  |        |
|--|--------|
| Production Rate (klb/hr)                         | 16.9   |
| Reactor Temperature (° F.)                       | 187.5  |
| Reactor Pressure (psig)                          | 294.3  |
| Condensing Level (%)                             | 0.0    |
| Level of Fluidized Bed (ft)                      | 46.4   |
| Ethylene Partial Pressure                        | 204.2  |
| Hydrogen/Ethylene Molar Ratio (ppm/mole percent) | 4.8    |
| Hexene/Ethylene Molar Ratio (%)                  | 1.6    |
| Bulk Density of Fluidized Bed (lb/cu. ft.)       | 22.4   |
| Melt Index of Polymer Bed                        | 0.99   |
| Density of Resin in Fluidized Bed (g/cm3)        | 0.9178 |
| Weight of Fluidized Bed (klb)                    | 156.9  |

As see in FIG. 2, as the superficial gas velocity in the reactor was changed the entrainment static also changed. Therefore, reducing or lowering the superficial gas velocity during the idling or start up procedures can decrease the entrainment static and lead to reductions in sheeting and fouling in the reactor.

All numerical values are “about” or “approximately” the indicated value, and take into account experimental error and variations that would be expected by a person having ordinary skill in the art.

All documents cited herein are fully incorporated by reference to the extent such disclosure is not inconsistent with this application and for all jurisdictions in which such incorporation is permitted.

While the foregoing is directed to embodiments of the present invention, other and further embodiments of the invention may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.

What is claimed is:

1. A method for idling a gas phase polymerization reactor, comprising:

introducing a polymerization neutralizer to the reactor in an amount sufficient to stop polymerization therein; stopping recovery of a polymer product from the reactor; stopping introduction of a catalyst feed and a reactor feed to the reactor;

adjusting a pressure within the reactor from an operating pressure to an idling pressure;

adjusting a superficial velocity of a cycle fluid through the reactor from an operating superficial velocity to an idling superficial velocity; and

maintaining the reactor in an idled state for a period of time, wherein the operating pressure ranges from about 1,800 kPag to about 2,300 kPag, and wherein the idling pressure ranges from about 650 kPag to about 800 kPag, and wherein the operating superficial velocity is greater than about 0.65 m/s and the idling superficial velocity ranges from about 0.50 m/s to about 0.65 m/s.

2. The method of claim 1, further comprising adjusting a composition of the cycle fluid within the reactor from an operating composition to an idling composition.

3. The method of claim 1, wherein the polymerization neutralizer comprises carbon monoxide and the concentration of the polymerization neutralizer within the reactor is greater than about 1 ppmv.

4. A method for idling a gas phase polymerization reactor, comprising:

stopping polymerization within the reactor by introducing a polymerization neutralizer comprising carbon monox-

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ide to the reactor such that the concentration of carbon monoxide within the reactor is at least 5 ppmv;  
 stopping recovery of a polymer product;  
 stopping introduction of a catalyst feed and a reactor feed to the reactor;  
 reducing a concentration of hydrocarbons within the reactor to produce a gas mixture within the reactor that comprises less than about 20 vol % hydrocarbons and about 80 vol % or more inert gases;  
 reducing a pressure within the reactor from an operating pressure to an idling pressure;  
 reducing an operating superficial velocity of a cycle fluid flowing through the reactor from an operating superficial velocity to an idling superficial velocity, wherein the cycle fluid comprises the gas mixture; and  
 maintaining the reactor in an idled state for a period of time, wherein the operating pressure ranges from about 1,800 kPag to about 2,300 kPag, and wherein the idling pressure ranges from about 650 kPag to about 800 kPag; and wherein the operating superficial velocity is greater than about 0.65 m/s and the idling superficial velocity ranges from about 0.50 m/s to about 0.65 m/s.

5. The method of claim 1, further comprising:  
 reducing a concentration of the polymerization neutralizer within the reactor;  
 reintroducing the reactor feed to the reactor;  
 adjusting the pressure within the reactor from the idling pressure to the operating pressure or a pressure intermediate the idling pressure and the operating pressure; and  
 adjusting the superficial velocity of cycle fluid flowing through the reactor to the operating superficial velocity or a superficial velocity intermediate the idling superficial velocity and the operating superficial velocity.

6. The method of claim 5, further comprising reintroducing the catalyst feed to the reactor and restarting recovery of the polymer product from the reactor.

7. The method of claim 6, wherein the catalyst feed reintroduced to the reactor is different than the catalyst feed in use prior to introducing the polymerization neutralizer.

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8. The method of claim 5, wherein the reactor feed reintroduced to the reactor is different than the reactor feed in use prior to introducing the polymerization neutralizer.

9. The method of claim 6, wherein a level of distributor plate fouling within the reactor from the time the polymerization neutralizer is introduced to the time recovery of the polymer product is restarted is less than about 3%.

10. The method of claim 1, wherein the reactor feed comprises at least one of ethylene, propylene, butene, pentene, hexene, heptene, and octene, and at least one of propane, butane, isobutane, pentane, isopentane, and hexane.

11. The method of claim 1, further comprising adjusting a temperature within the reactor from an operating temperature to an idling temperature after the polymerization neutralizer is introduced to the reactor.

12. The method of claim 1, wherein the operating temperature ranges from about 75° C. to about 110° C. and the idling temperature is less than about 90° C.

13. The method of claim 1, further comprising raising a height of a fluidized bed within the reactor from an operational height to a pre-idling height before introducing the polymerization neutralizer to the reactor.

14. The method of claim 1, wherein the catalyst feed comprises a metallocene catalyst.

15. The method of claim 1, further comprising introducing additional polymerization neutralizer to the reactor during the period of time to maintain a minimum concentration of 5 ppmv.

16. The method of claim 1, wherein the cycle fluid has an operating condensed level of about 15 wt % or more.

17. The method of claim 1, further comprising reducing the condensed level of the cycle fluid to less than about 15 wt %.

18. The method of claim 1, further comprising reducing the condensed level of the cycle fluid to an idling condensed level, wherein the idling condensed level is less than about 5 wt %.

19. The method of claim 4, wherein the carbon monoxide is introduced to the reactor upon detection of one or more shut down indicators.

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